Effect of Radial Head Implant Shape on Radiocapitellar using an Image-Based Tool to Examine Joint Congruency


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Disclosures:

Introduction: Radial head arthroplasty is indicated in fractures where extensive comminution and bone loss are present. Many types of radial head implants have been developed varying in materials, methods of fixation and modularity. Of specific interest in this study, current radial head designs also vary in geometry. Previous anthropometric studies have shown that the radial head is not circular but it is also not consistently elliptical (King et al., 2001). The radial head articulates with the capitellum of the distal humerus as well as the lesser sigmoid notch of the proximal ulna. As such, alterations in the geometry of the radial head implant are likely to have implications on the resulting joint congruency and contact mechanics. The purpose of this study was to investigate the effect of implant shape on radiocapitellar joint congruency using non-invasive image-based methods.

Methods: Joint congruency was evaluated in 4 cadaveric specimens (Male: 73±13 years) employing a previously developed inter-bone distance algorithm (Lalone et al. 2012). Muscle tendons were attached to pneumatic actuators of a previously developed elbow loading simulator to rotate the forearm from full pronation to supination (Ferreira et al. 2010). Forearm rotation was performed both passively and actively after implantation of an axisymmetric radial head, a population-based quasi-anatomic radial head implant design, and a reverse engineered radial head implant. All radial heads were formed out of ABS plastic using a rapid prototyping machine and inserted using computer navigation (Deluce et al. 2011). X-ray CT scans were acquired prior to testing to create 3D reconstructions of the proximal radius and distal humerus. Rigid-body landmark registration was used to align the 3D CT models to the specimen during testing (Lalone et al., 2013). Inter-bone distances were measured to investigate the relative position of the native capitellum to the implanted radial head to assess overall joint congruency. Distances were displayed using contour maps for each radial head scenario. Surface area was measured for four levels of inter-bone distances (0.5mm, 1.5mm, 2.5mm and 3.5mm). A two-way repeated anova was performed to detect statistical differences in surface area between implanted radial heads. Significance was set at p=0.05.

Results: Figure 1 shows the joint congruency after implantation of the three radial head implants. As the forearm rotates from pronation to supination, the region of close proximity (shown from red-blue) rotates from the dorsal-medial region of the radial head to the dorsal lateral region in a counter-clockwise rotation. During simulated active forearm rotation, there were no statistical differences in the regions of close proximity (surface area on the radial head that is has an inter-surface distance less than 3.5mm, 2.5mm, 1.5mm, and 0.5mm) across radial head implants (p= 0.30,0.28,0.01,0.42 respectively) as shown in Figure 2. During passive forearm rotation, no significant differences in the regions of close proximity (surface area on the radial head that is has an inter-surface distance of less than 3.5mm, 2.5mm, 1.5mm, and 0.5mm) were found across radial head implants (p= 0.30,0.13,0.32, 0.41 respectively).

Discussion: Previous investigations examining the effect of radial head implant shape on joint contact area surface area and location have also shown no significant differences among implant morphologies using bench top studies (Shannon et al. 2012). In this current study using intact elbows, the overall joint congruency (as defined by the surface area on the radial head) was not affected by the radial head implant shape. The interactions of the concave surface of the implants with the convex surface of the capitellum and the articular margin of the radial head with the concave surface of the proximal ulna and the constraint of the annular ligament may have an important influence on the motion patterns of the radial head and hence the contact mechanics during forearm rotation. Additional specimens are needed to potentially detect differences related to implant shape. Additionally, future work is needed to investigate the effect of material choice and implantation to investigate their role on the resulting joint contact mechanics.

Significance: Preliminary results from this current study investigate overall joint congruency suggests that perhaps the radial head implant shape does not have an important effect on radiocapitellar joint mechanics.

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Figure 1: Joint congruency of a single specimen following the implantation of the axisymmetric, quasi anatomic and reverse-engineered radial head implants.

Note: The radial head is shown in a single orientation (dorsal pointed superiorly, volar pointed inferiorly).

Figure 2: Surface area on the radial head with an inter-bone distance less than 3.5mm (n=4+1SD) between implant types during simulated active forearm rotation.